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A Search for New Physics in Like-Sign Dileptons using the Inclusive High p_T Lepton Sample

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Abstract

We describe a search for New Physics in 704 pb^{-1} of data, collected using the CDF II detector in Run II. We use a sample of two identified leptons of the same charge (“like-sign dileptons”). We compare the number of expected same sign dilepton events to the number of observed events.

Preliminary Results for Winter 2006 Conferences

1 Introduction

This note describes a search for New Physics in $\bar{p}p$ collisions at $\sqrt{s} = 1.96$ TeV with the CDF II detector at the Fermilab Tevatron. We select a sample of like-sign dileptons. The CDF detector is described in detail in [1].

The number of events expected from the Standard Model is very low, making this search sensitive to New Physics with three or more leptons, such as SUSY trilepton signatures, or signals with Majorana particles, such as $\tilde{g}\tilde{q}$ signatures with decays into leptons.

2 Data Sample & Event Selection

This analysis is based on the integrated luminosity of 704 pb^{-1} collected with the CDF II detector in Run II.

We do not impose any requirements on the event topology, such as presence or absence of jets in order not to limit this search to a particular New Physics scenario. We perform a “blind analysis” with a specified signal box. The modelling of the expected Standard Model background contributions to the signal region is tested in several control regions.

Dilepton candidate events are first identified in the trigger system by the requirement of at least one central electron or muon candidate with $P_T > 18 \text{ GeV}/c$ and $\cancel{E}_T > 15 \text{ GeV}$. After full event reconstruction, we require two same-sign lepton candidates, one of them has to be the trigger lepton with $E_T > 20 \text{ GeV}$ ($p_T > 20 \text{ GeV}$) for electrons (muons). The second lepton has to pass $E_T > 10 \text{ GeV}$ (e) or $p_T > 10 \text{ GeV}$ (μ). Both the leading and sub-leading lepton candidates must pass strict lepton identification requirements and have an isolated energy signature in the calorimeter. We also require a tracking isolation requirement for both leptons. The choice of a medium- p_t (sub-leading) lepton leg is motivated by the lower p_t range of leptons from supersymmetric $\tilde{\chi}^\pm\tilde{\chi}^0$ production, and gluino production, where the acceptance depends strongly on the choice of SUSY parameters. Fig. 1 shows the distributions of primary and secondary lepton p_t for same-sign Dileptons originating from $\tilde{\chi}^\pm\tilde{\chi}^0$ production (as an example, we chose an mSUGRA framework with $m_0 = 100$, $m_{1/2} = 180$ and $\tan\beta = 3$). A cut at 10 GeV for the secondary lepton allows for a reasonable acceptance while keeping the background from $W + \gamma$ events under control. Additionally, we require the missing transverse energy in the event to be $\cancel{E}_T > 15 \text{ GeV}$ to suppress the $Z + \gamma$ background. The invariant mass of primary and secondary leptons is required to be larger than 25 GeV . We apply this cut to reduce the contamination from $\bar{b}b$ production. The invariant mass of one of the two primary leptons and any second lepton of the same flavor and opposite sign in the event. This cut is designed to reduce the contamination from $Z/\gamma^* + \gamma$ where the photon converts and the electron is *not* identified as coming from a conversion.

3 Backgrounds

For this analysis, the dominant backgrounds are from events with a primary lepton and a secondary like-sign electron from an untagged conversion ($Z + \gamma$, $W + \gamma$). We apply unusually strict cuts to tag more conversions by setting a separation cut between the two leptons to $s = 1.1 \text{ cm}$ and an angular cut to $\delta \cot \theta = 0.26$. These cuts were selected optimizing the ratio of signal to background in Monte Carlo studies and comparing to the data. Smaller backgrounds include WW , ZZ and $t\bar{t}$ events. They are also estimated using Monte Carlo samples.

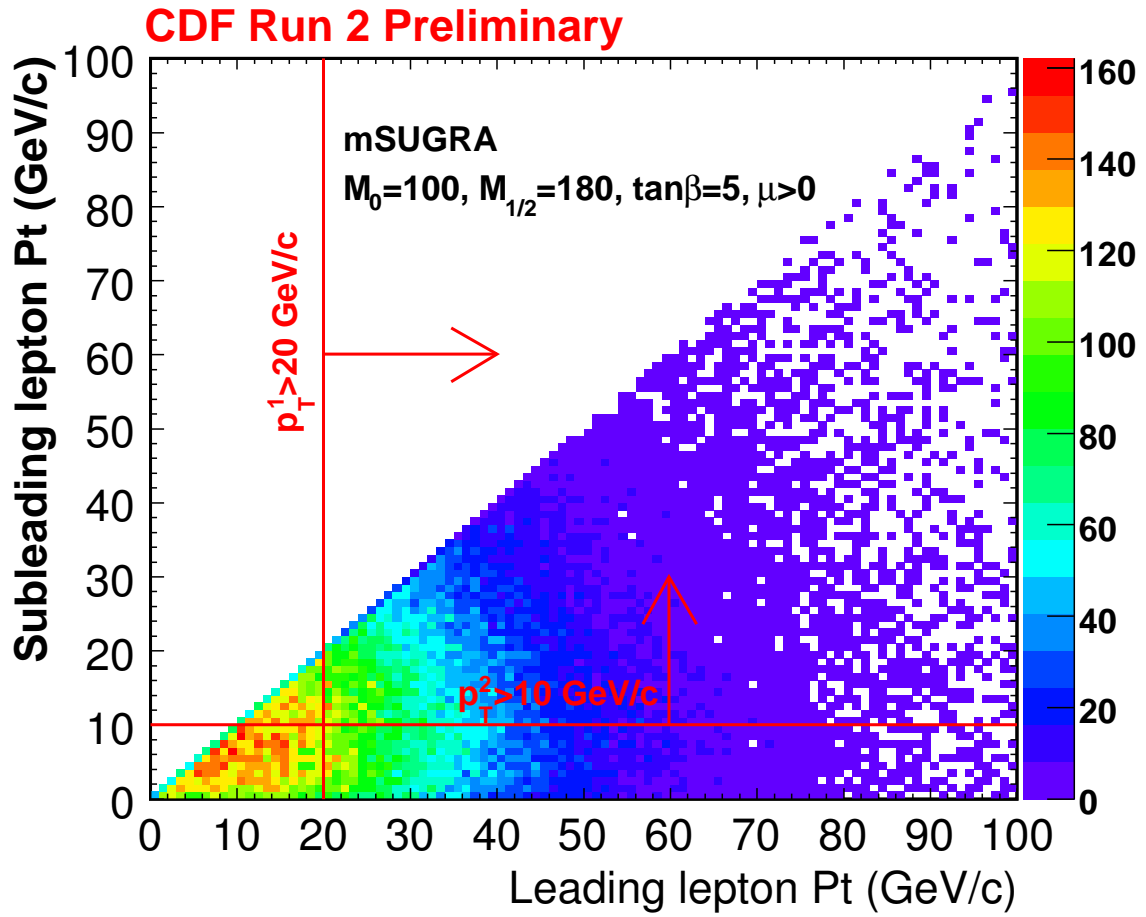


Figure 1: Generator-level transverse momentum distribution for the leading and subleading same-sign leptons for $\tilde{\chi}^\pm \tilde{\chi}^0$ production in an mSUGRA framework. The required minimum transverse momentum for the leading (sub-leading) lepton is $p_T > 20 \text{ GeV}$ ($p_T > 10 \text{ GeV}$).

channel	ee	$e\mu$	$\mu\mu$	combined
$\tilde{\chi}^{\pm}\tilde{\chi}^0$	0.64	1.64	0.91	3.19
Drell Yan	0.42	0.81	0.0	1.23
$\bar{t}t$	0.0	0.02	0.0	0.02
Diboson	0.21	0.46	0.24	0.91
$W + \gamma$	1.38	1.72	0.27	3.37
Fakes	0.53	0.53	0.22	1.28
total pred.	3.18	5.18	1.66	9.99
stat. uncert.	0.32	0.25	0.08	0.49

Table 1: Event counts in the signal region for the Standard Model backgrounds and a sample data point from mSugra $\tilde{\chi}^{\pm}\tilde{\chi}^0$ production.

We estimate the background from events with one W and a jet which fakes an isolated electron or muon using data. We determine a *per isolated track* fake rate, i.e. the denominator is the number of isolated tracks, and the numerator is the number of identified leptons in a data sample triggered by at least one jet with $E_T > 50$ GeV. The muon and electron fake rates are essentially sample-independent, i.e. the variation in fake rate derived from different trigger samples is small.

4 Expected number of events

Tab. 1 shows the event counts in the signal region for the Standard Model backgrounds and a sample data point from mSugra $\tilde{\chi}^{\pm}\tilde{\chi}^0$ production, for ee, $e\mu$ and $\mu\mu$ pairs. The signal to background ratio is 0.3. Note that the largest background contribution is still from residual conversions.

5 Control Regions

We test our modeling of high momentum leptons, as well as our luminosity estimate in the Drell-Yan sample at the Z peak and find good agreement with the expected Z cross-section. We also test our low-mass lepton background modeling by comparing prediction and observation in a $\gamma^*/Z \rightarrow \ell\ell$ sample excluding the region around the Z pole. Other control samples include samples with same-sign leptons, conversion enriched samples (here the conversion cuts are inverted), and samples with varying E_T cuts. Fig. 2 shows a summary of the data/MC ratio for all control regions described above, for the e-e category. We conclude that our backgrounds are modelled reasonably well across all control regions. Fig.3 shows the control region agreement of MC and data for the $e - \mu$ and $\mu - \mu$ categories.

6 Systematic uncertainties

The dominant systematic uncertainty on the number of predicted background events comes from limited MC statistics as well as the uncertainty due to the modelling of conversions. Tab. 2 shows the systematic uncertainties as the percentage of the expected central values for each lepton category.

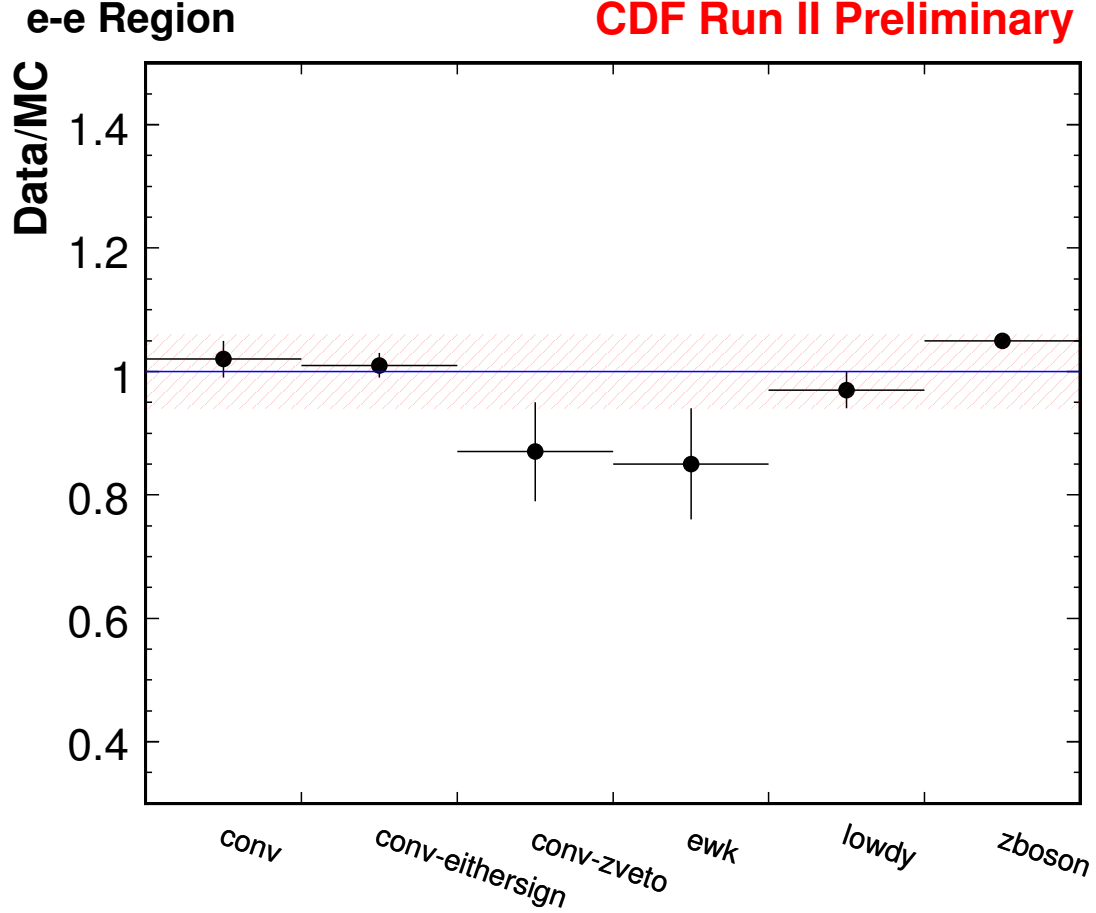


Figure 2: Summary plot for control regions, $e - e$ category only. Shown is the data/MC ratio. Red: linear fit for all control regions, blue: ideal case of data/MC ratio of 1. The shaded region represents the systematic uncertainty.

Systematic	ee	$e\mu$	$\mu\mu$	Overall
ID	0.5	0.8	1.0	0.7
Luminosity	4.7	5.1	4.2	4.9
Conversion eff.	11.9	12.7	0.0	11.0
Theory	4.5	4.3	4.9	4.5
MC statistics	10.7	11.3	6.8	7.1
QCD (fakes)	3.5	2.0	3.9	3.8
Total	17.6	18.4	10.2	15.0

Table 2: Systematic uncertainties as percentage of the predicted number of events in each category

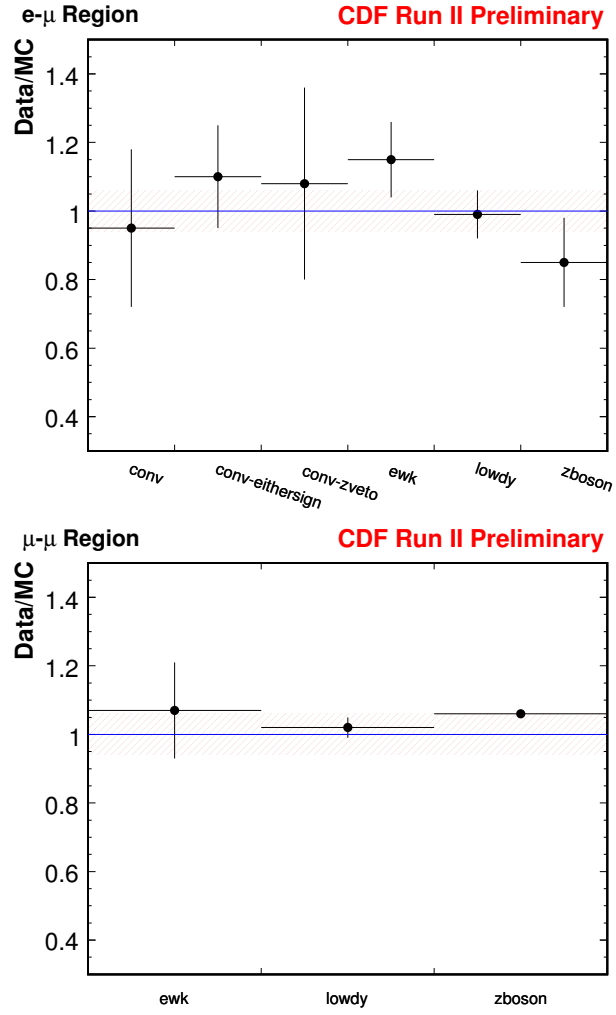


Figure 3: Summary plot of data/MC ratio for control regions, $e - \mu$ category (top) and $\mu - \mu$ category (bottom). The blue line represents the ideal case of a data/MC ratio of 1. The shaded region represents the systematic uncertainty.

Category	Obs.	Pred.
ee	4	2.6 ± 0.4
$e\mu$	5	3.5 ± 0.6
$\mu\mu$	0	0.7 ± 0.1
Total	9	6.8 ± 1.0

Table 3: Final counts per lepton category observed in the signal region and the predicted SM contribution with systematic uncertainty

7 Signal region

Opening the signal box, we observe 9 events, as shown in Tab. 3. We expect 6.8 ± 1.0 events from background. Fig. 4 and Fig. 7 show several kinematic distribution of interest for events found in the signal region.

The number of observed events is consistent with the background prediction. *A posteriori*, we cannot unambiguously quantify the significance of the excess of events in the tail of the leading lepton transverse momentum distribution shown in Fig. 4. We look forward to adding more data.

8 Event Displays

Fig. 6 and following show the event display of the highest E_T event. This event has two electrons with $E_T > 100$ GeV, a photon with $E_T = 15$ GeV and a third, low-momentum, non-isolated electron with $E_T = 5$ GeV. We show the $r\phi$, rz , and lego (calorimeter) views of this event.

References

- [1] CDF II Collaboration, FERMILAB-PUB-96/390-E.
- [2] Joel Heinrich, *Bayesian limit software: multi-channel with correlated backgrounds and efficiency*, CDF/MEMO/STATISTICS/PUBLIC/7587

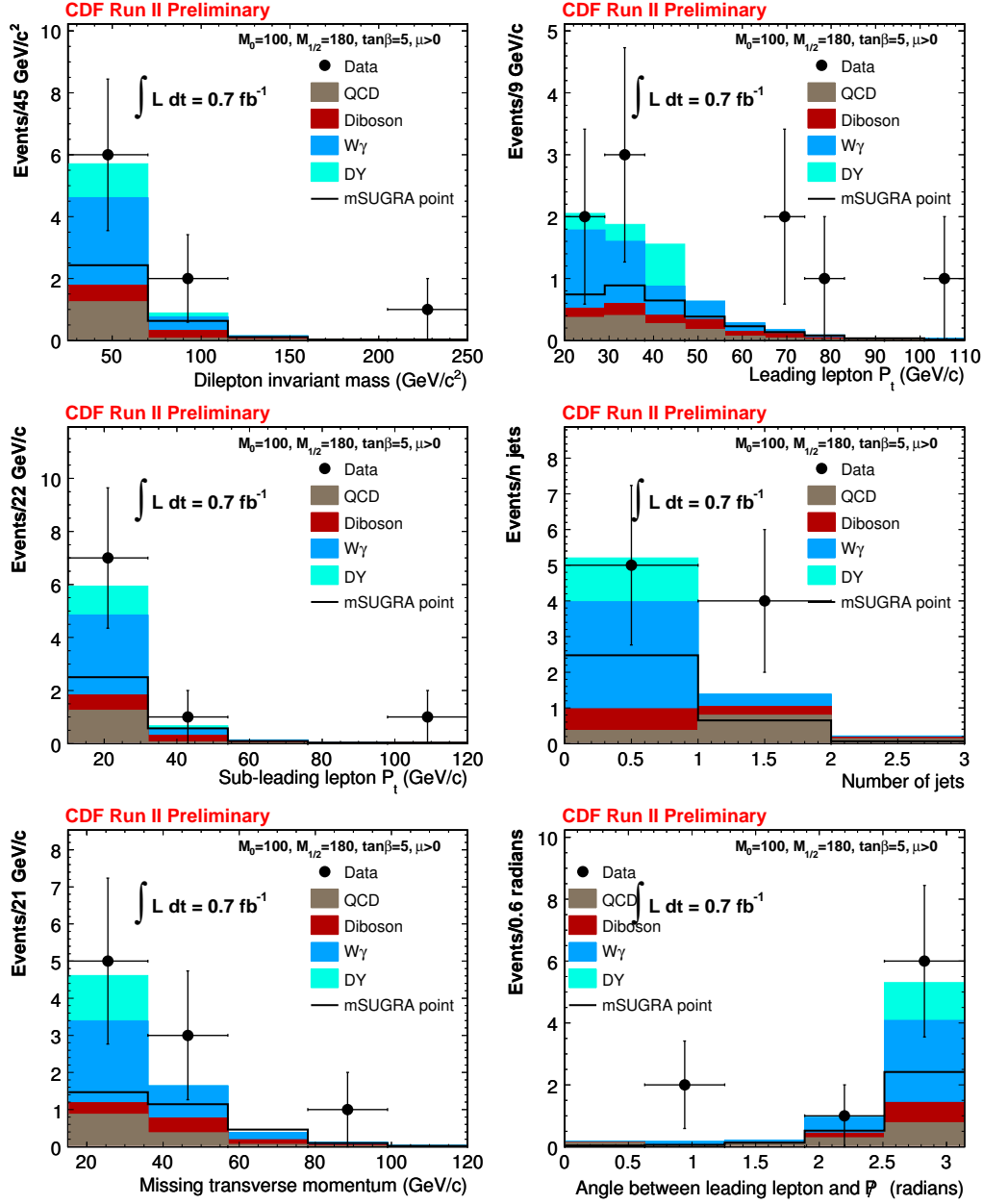


Figure 4: The kinematic distributions of the events found in the signal region. In particular, the leading lepton transverse momentum shows an excess at high momentum.

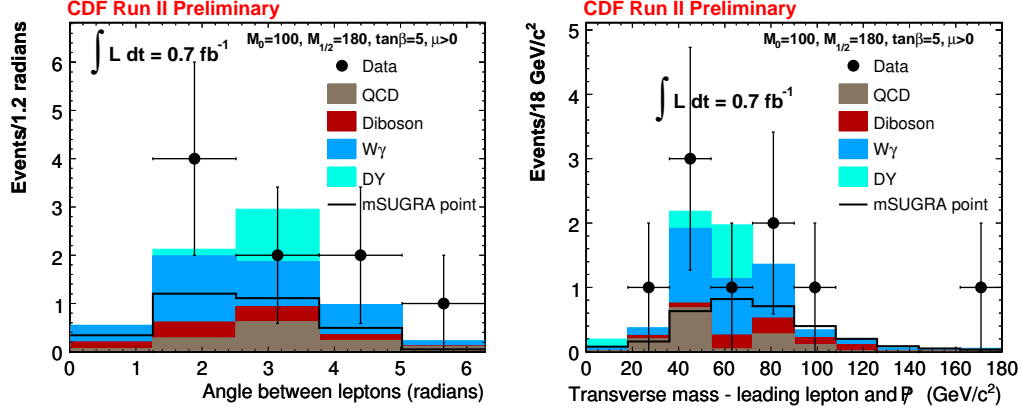


Figure 5: More kinematic distributions of the events found in the signal region.

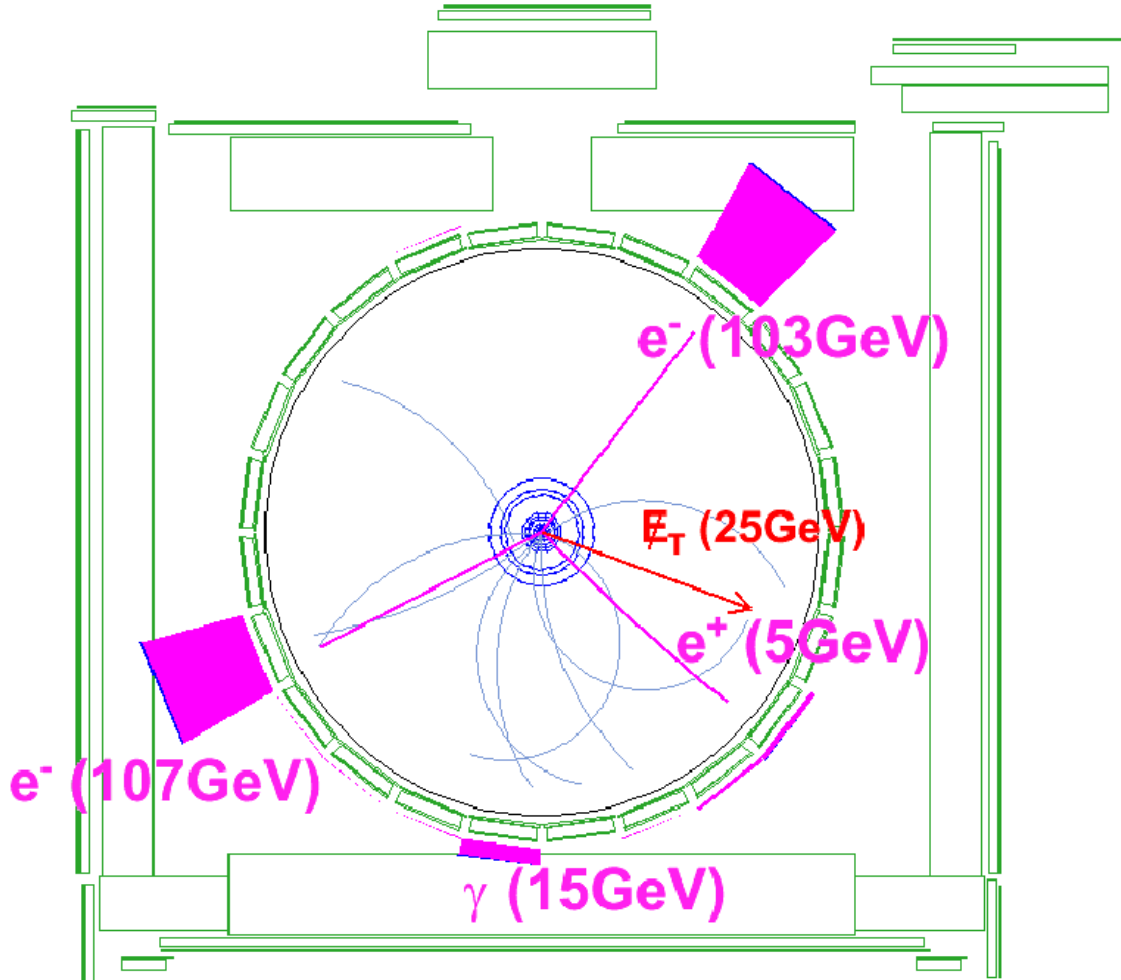


Figure 6: Run 197079, event 2262178. COT view.

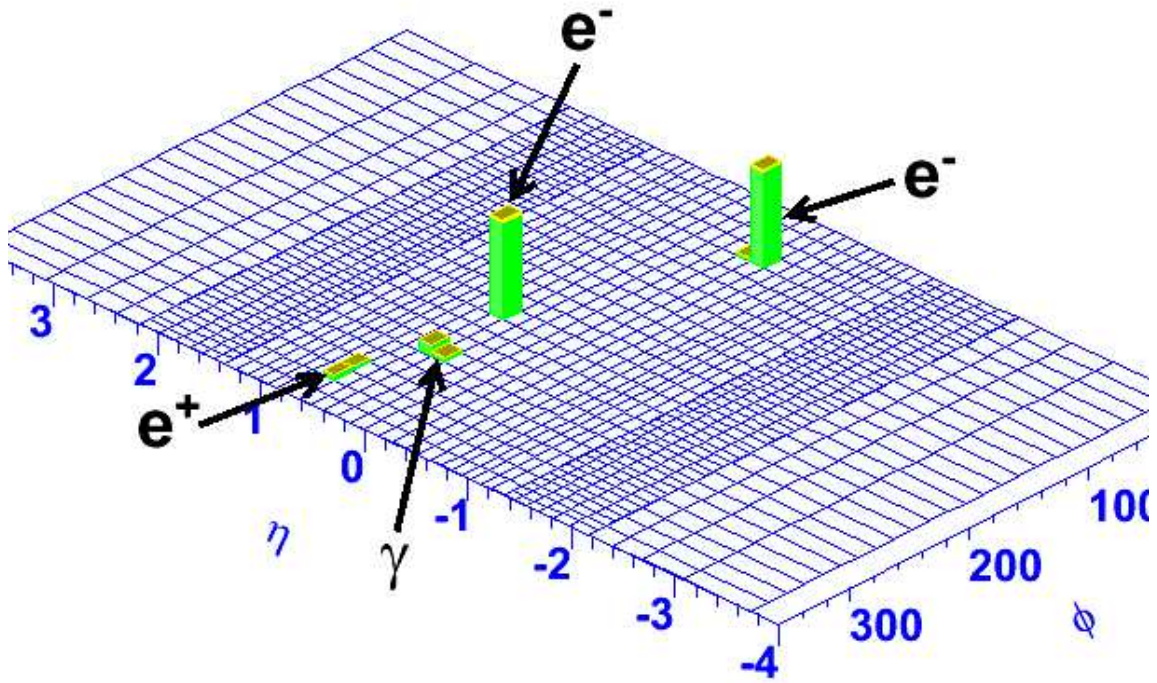


Figure 7: Run 197079, event 2262178. Lego view with 1 GeV cut applied to all calorimeter towers.

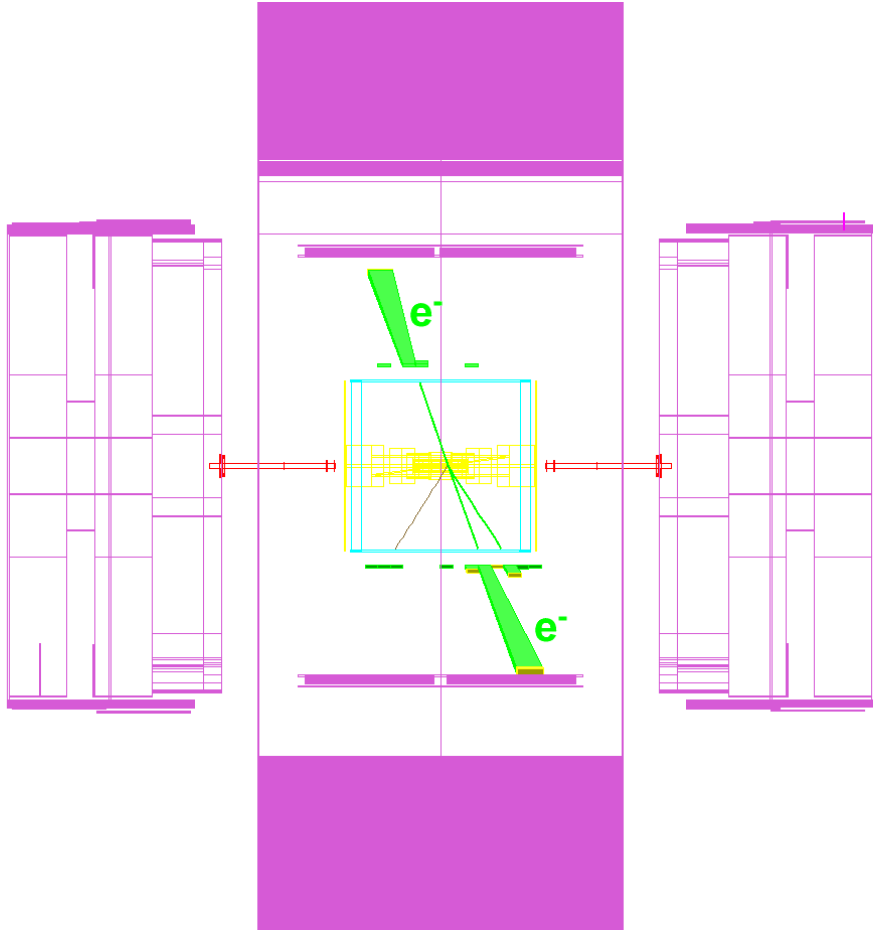


Figure 8: Run 197079, event 2262178. rz view.